TITLE OF THE INVENTION

BAND REJECTION FILTER WITH POLES

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a band rejection filter with poles that is provided with two or more resonant circuits.

Description of Related Art

Conventionally, band rejection filters provided with two or more resonant circuits are known (for example, refer to "Microwave Filters, Impedance-Matching Networks, and Coupling Structures", G. Matthaei, et al., Artech House Publishers, 1980, pp. 735). In general, a band rejection filter is provided with two or more series resonant circuits 200 connected in series via a transmission line 201, as shown in Fig. 11. The transmission line 201 is the one that has a length equal to the one-quarter wavelength at the resonance frequency of the two or more series resonant circuits 200. The band rejection filter is also provided with an input/output terminal 203 having an impedance Zo.

Since the electric nodes of each series resonant circuit 200 are electrically short-circuited at the resonance frequency of the two or more series resonant circuits 200, the band rejection filter exhibits characteristics of having an infinite attenuation at the resonance frequency of the two or more series resonant circuits 200 and having a limited attenuation in the vicinity of the resonance frequency. A problem with the conventional band rejection filter mentioned above is that in some cases the number of series resonant circuits required to obtain a desired attenuation in

a certain frequency band has to be increased and therefore the circuit scale has to be increased. Another problem is that a so-called attenuation pole that provides a maximum attenuation is always formed only at the resonance frequency of the plurality of resonant circuits, and it is therefore difficult to provide a sufficient attenuation in a frequency range of frequencies close to the resonance frequency.

SUMMARY OF THE INVENTION

The present invention is made in order to solve the above-mentioned problems, and it is therefore an object of the present invention to provide a band rejection filter with poles that can improve its attenuation characteristics over a desired frequency band, and can reduce the number of resonant circuits included in the band rejection filter, thereby reducing the circuit scale.

In accordance with an aspect of the present invention, there is provided a band rejection filter with poles including a plurality of series resonant circuits having end terminals connected in common and other end terminals connected in series via a plurality of transmission lines each having a length that is an odd multiple of about a one-quarter wavelength at a resonance frequency of the plurality of series resonant circuits, and a jump-coupling circuit for roughly coupling two of the plurality of series resonant circuits, which are not adjacent to each other, to each other.

Therefore, the aspect of the present invention offers an advantage of being able to improve the attenuation characteristics of the band rejection filter with poles over a desired frequency band, and to reduce the number of resonant

circuits included in the band rejection filter, thereby reducing the circuit scale of the band rejection filter.

In accordance with another aspect of the present invention, there is provided a band rejection filter with poles including a plurality of parallel resonant circuits connected in series via a plurality of transmission lines each having a length that is an odd multiple of about a one-quarter wavelength at a resonance frequency of the plurality of parallel resonant circuits, and a jump-coupling circuit for roughly coupling two of the plurality of parallel resonant circuits, which are not adjacent to each other, to each other.

Therefore, the other aspect of the present invention offers an advantage of being able to improve the attenuation characteristics of the band rejection filter with poles over a desired frequency band, and to reduce the number of resonant circuits included in the band rejection filter, thereby reducing the circuit scale of the band rejection filter.

Further objects and advantages of the present invention will be apparent from the following description of the preferred embodiments of the invention as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a plan view showing the structure of a band rejection filter with poles in accordance with embodiment 1 of the present invention;

Figs. 2A and 2B are diagrams showing an equivalent circuit of the band rejection filter with poles in accordance with embodiment 1 of the present invention;

Figs. 3A to 3B are diagrams showing an equivalent circuit

of an admittance inverter used by the band rejection filter with poles in accordance with embodiment 1 of the present invention;

Fig. 4 is a diagram showing an example of calculation of the characteristics of the band rejection filter with poles in accordance with embodiment 1 of the present invention;

Fig. 5 is a plan view showing the structure of a band rejection filter with poles in accordance with embodiment 2 of the present invention;

Fig. 6 is a plan view showing the structure of a band rejection filter with poles in accordance with embodiment 3 of the present invention;

Figs. 7A and 7B are a cross-sectional view and a top plan view showing the structure of a band rejection filter with poles in accordance with embodiment 4 of the present invention;

Fig. 8 is a circuit diagram showing an equivalent circuit of the band rejection filter with poles in accordance with embodiment 4 of the present invention;

Figs. 9A and 9B are a cross-sectional view and a top plan view showing the structure of a band rejection filter with poles in accordance with embodiment 5 of the present invention;

Fig. 10 is a plan view showing the structure of a band rejection filter with poles in accordance with embodiment 6 of the present invention; and

Fig. 11 is a diagram for explaining a prior art band rejection filter.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The preferred embodiment of the invention will now be described with reference to the accompanying drawings.

Embodiment 1.

Fig. 1 is a plan view showing the structure of a band rejection filter with poles in accordance with embodiment 1 of the present invention. The band rejection filter with poles includes a transmission line 2 and a plurality of open-ended stubs 3_1 to 3_6, each of which is formed of a microstrip line on a dielectric substrate 1, and jump-coupling circuits 4_1 and 4_2 formed on the dielectric substrate 1.

The transmission line 2 is formed of two parallel line segment patterns having ends connected to each other and other ends that are open. The open ends of the transmission line 2 are used as input/output terminals 5_1 and 5_2.

Each of the plurality of open-ended stubs 3_1 to 3_6 functions as a series resonant circuit. Each of the plurality of open-ended stubs 3_1 to 3_6 has a length equal to the one-quarter wavelength at the resonance frequency of the series resonant circuit, and is projecting to outside from the transmission line 2. In accordance with the present invention, each of the open-ended stubs 31 to 36 does not need to strictly have a length equal to the one-quarter wavelength and can alternatively have a length that is an odd multiple of about the one-quarter wavelength. In this case, an intended result is produced. Therefore, "the one-quarter wavelength", which is simply described in this specification, means "an odd multiple of about the one-quarter wavelength". The plurality of open-ended stubs 3_1 to 3_6 are arranged at predetermined intervals of the one-quarter wavelength at the resonance frequency of the plurality of series resonant circuits.

The first jump-coupling circuit 4_1 is arranged between the first open-ended stub 3_1 and the sixth open-ended stub 3_6,

and the second jump-coupling circuit 4_2 is arranged between the second open-ended stub 3_2 and the fifth open-ended stub 3_5.

The first jump-coupling circuit 4_1 includes a capacitor 41_1, a transmission line 41_3, and another capacitor 41_2 which are connected in series. The capacitor 41_1 has the same structure as the other capacitor 41_2, and they are both chip capacitors. The transmission line 41_3 is formed of a microstrip line having a length equal to the one-quarter wavelength at the resonance frequency of the plurality of series resonant circuits.

Similarly, the second jump-coupling circuit 4_2 includes a capacitor 42_1, a transmission line 42_3, and another capacitor 42_2 which are connected in series. The capacitor 42_1 has the same structure as the other capacitor 42_2, and they are both chip capacitors. The transmission line 42_3 is formed of a microstrip line having a length equal to the one-quarter wavelength at the resonance frequency of the plurality of series resonant circuits. Each of those jump-coupling circuits 4_1 and 4_2 constitutes an admittance inverter mentioned later.

In the band rejection filter with poles according to this embodiment 1, each of the above-mentioned capacitors 41_1, 41_2, 42_1, and 42_2 consists of a chip capacitor. As an alternative, each of the above-mentioned capacitors 41_1, 41_2, 42_1, and 42_2 can consist of either a gap capacitor formed as a gap of the transmission line, or an interdigital capacitor. Each of the transmission lines 2, 41_3 and 42_3 is formed of a microstrip line. As an alternative, each of the transmission lines 2, 41_3 and 42_3 can be formed of either a slot line or a coplanar line.

In general, the band rejection filter with poles can be represented by an equivalent circuit as shown in Fig. 2A. In other words, the band rejection filter with poles includes 2n (n is an integer number equal to or larger than 2) series resonant circuits 30_1 to 30_{2n} having terminals that are connected in common (for example, that are grounded), and other terminals that are connected in series via a plurality of transmission lines 20_1 to 20_{2n-1} each having a length equal to the one-quarter wavelength at the resonance frequency of the plurality of series resonant circuits. The band rejection filter with poles having the structure as shown in Fig. 1 corresponds to an example of the equivalent circuit of Fig. 2A in which "n" is set to "3".

A first admittance inverter 40_1 comprised of the first jump-coupling circuit 4_1 is connected between the first series resonant circuit 30_1 and the 2n-*th* series resonant circuit 30_{2n}, and a second admittance inverter 40_2 comprised of the second jump-coupling circuit 4_2 is connected between the second series resonant circuit 302 and the (2n-1)-*th* series resonant circuit 30_{2n-1}. The parameter J values of the first admittance inverter 40_1 and the parameter J values of the second admittance inverter 40_2 are both negative, and are represented by "$-J_1$" and "$-J_2$", respectively.

Input/output terminals 50_1 and 50_2 each having a source impedance Zo are connected to the first and 2n-*th* series resonant circuits 30_1 and 30_{2n}, respectively.

In general, each of the first and second admittance inverters 40_1 and 40_2 having negative parameter J values, as shown in the equivalent circuit of Fig. 2A, can be expressed by admittance inverters "$\pm J_i$", "J_i^2/J" and "$\pm J_i$", which are

connected in series, as shown in Fig. 3A. In general, an admittance inverter is approximately implemented via either a transmission line having a length equal to the one-quarter wavelength or a circuit including an in-series capacitor.

Therefore, the above-mentioned admittance inverter $\pm J_i$ can be approximately replaced by an in-series capacitor having a capacitance value of J_i/ω (ω is an operating angular frequency), as shown in Fig. 3B. The admittance inverter J_i^2/J can be approximately replaced by a transmission line having a length equal to the one-quarter wavelength and a characteristic admittance J_i^2/J, as shown in Fig. 3C. As a result, when "n" is "3", the band rejection filter with poles represented by the equivalent circuit of Fig. 2A can have a structure as shown in Fig. 1. In other words, the circuitry having the structure as shown in Fig. 1 exhibits the characteristics of band rejection filters with poles.

The equivalent circuit of the band rejection filter with poles as shown in Fig. 2A can be shown by a further-simplified block diagram shown in Fig. 2B. The band rejection filter with poles shown in Fig. 2B contains, as coupling among the plurality of series resonant circuits 30_1 to 30_{2n}, a plurality of main couplings each between two adjacent series resonant circuits and a plurality of jump couplings between two series resonant circuits that are not adjacent to each other. The band rejection filter with poles according to this embodiment 1 is thus characterized in that it has a plurality of jump couplings each for providing coupling between two series resonant circuits that are not adjacent to each other in addition to a plurality of main couplings each for providing coupling between two adjacent series resonant circuits, as shown in Fig.

2B. Those jump-couplings provide two or more paths along which electromagnetic waves propagate among the plurality of series resonant circuits, and, when the electromagnetic waves are of opposite phase with one another, an attenuation pole is formed and therefore the components propagating through the paths cancel one another out.

Fig. 4 shows an example of calculation of the characteristics of the band rejection filter with poles having four stages. It is clear from this figure that the band rejection filter with poles produces attenuation poles that provide a minimum amount of pass through on both sides of the resonance frequency of the series resonant circuits. Fig. 4 also shows the characteristics of a band rejection filter without poles having the same number of stages, band width, and reflection loss as the band rejection filter with poles mentioned above using a dashed line. It is clear from the figure that the band rejection filter with poles that is so formed as to have jump couplings can provide a desired attenuation for a desired attenuation band.

As previously explained, according to this embodiment 1, the first and sixth series resonant circuits 3_1 and 3_6 that are not adjacent to each other are coupled to each other via the first jump-coupling circuit 4_1 in which a capacitor 41_1, a transmission line 41_3 having a length equal to the one-quarter wavelength, and another capacitor 41_2 are connected in series, and the second and fifth series resonant circuits 3_2 and 3_5 that are not adjacent to each other are coupled to each other via the second jump-coupling circuit 4_2 in which a capacitor 42_1, a transmission line 42_3 having a length equal to the one-quarter wavelength, and another capacitor 42_2 are connected in series.

Therefore, a band rejection filter with poles having two or more attenuation poles in its filter characteristics can be implemented. As a result, since the number of filters required for providing a desired attenuation can be reduced, the downsizing of the circuitry can be achieved.

Embodiment 2.

A band rejection filter with poles according to embodiment 2 of the present invention employs jump-coupling circuits in each of which a high impedance line, a low impedance line, and another high impedance line are connected in series, instead of the jump-coupling circuits according to embodiment 1.

Fig. 5 is a plan view showing the structure of the band rejection filter with poles in accordance with this embodiment 2. The same components as those of embodiment 1 or like components are designated by the same reference numerals as shown in embodiment 1, and therefore the explanation of those components will be omitted hereafter.

A first jump-coupling circuit 4_1 includes a high impedance line 43_1, a low impedance line 43_3, and another high impedance line 43_2 that are connected in series. The two high impedance lines 43_1 and 43_2 have their respective bent portions that are formed so that their impedances are increased, and each of them is formed of a microstrip line having a length equal to the one-quarter wavelength at the resonance frequency of series resonant circuits. The low impedance line 43_3 is formed of a linear microstrip line having a length equal to the one-quarter wavelength at the resonance frequency of the series resonant circuits.

A second jump-coupling circuit 4_2 includes a high impedance line 44_1, a low impedance line 44_3, and another high impedance line 44_2 that are connected in series. The two high impedance lines 44_1 and 44_2 have their respective bent portions that are formed so that their impedances are increased, and each of them is formed of a microstrip line having a length equal to the one-quarter wavelength at the resonance frequency of the series resonant circuits. The low impedance line 44_3 is formed of a linear microstrip line having a length equal to the one-quarter wavelength at the resonance frequency of the series resonant circuits.

In the band rejection filter with poles according to this embodiment 2, each of the above-mentioned high impedance lines 43_1, 43_2, 44_1, and 44_2 and the above-mentioned low impedance lines 43_3 and 44_3 is formed of a microstrip line, as previously mentioned. As an alternative, each of them can be formed of either a slot line or a coplanar line.

When the admittance inverter $\pm J_i$, which is already explained with reference to Fig. 3, is formed of a line having a high impedance and a length equal to the one-quarter wavelength at the resonance frequency of the series resonant circuits, instead of a capacitor adopted by above-mentioned embodiment 1, the admittance inverter J_i^2/J can be implemented via a line having a low impedance and a length equal to the one-quarter wavelength at the resonance frequency of the series resonant circuits because J of the admittance inverter J_i^2/J generally becomes sufficiently small. Thus, each jump-coupling circuit of the band rejection filter with poles is constructed of a high impedance line, a low impedance line, and another high impedance line, each of which has a length

equal to the one-quarter wavelength at the resonance frequency of the band rejection filter, and which are connected in series.

As previously explained, according to this embodiment 2, the first and sixth series resonant circuits 3_1 and 3_6 that are not adjacent to each other are coupled to each other via the first jump-coupling circuit 4_1 in which a high impedance line 43_1, a low impedance line 43_3, and another high impedance line 43_2, each of which has a length equal to the one-quarter wavelength at the resonance frequency of the plurality of series resonant circuits, are connected in series, and the second and fifth series resonant circuits 3_2 and 3_5 that are not adjacent to each other are coupled to each other via the second jump-coupling circuit 4_2 in which a high impedance line 44_1, a low impedance line 44_3, and another high impedance line 44_2, each of which has a length equal to the one-quarter wavelength at the resonance frequency of the plurality of series resonant circuits, are connected in series. Therefore, a band rejection filter with poles having two or more attenuation poles in its filter characteristics can be implemented. As a result, since the number of filters required for providing a desired attenuation can be reduced, the downsizing of the circuitry can be achieved.

Embodiment 3.

A band rejection filter with poles according to embodiment 3 of the present invention employs jump-coupling circuits in each of which a microstrip line having a length sufficiently shorter than the wavelength at the resonance frequency of a plurality of series resonant circuits, a capacitor, and another microstrip line having a length

sufficiently shorter than the wavelength at the resonance frequency of the plurality of series resonant circuits are connected in series, instead of the jump-coupling circuits according to embodiment 1.

Fig. 6 is a plan view showing the structure of the band rejection filter with poles in accordance with this embodiment 3. The same components as those of embodiment 1 or like components are designated by the same reference numerals as shown in embodiment 1, and therefore the explanation of those components will be omitted hereafter.

A first jump-coupling circuit 4_1 is constructed of a microstrip line 45_1, a capacitor 45_3, and another microstrip line 45_2, which are connected in series. The first microstrip line 45_1 has the same structure as the second microstrip line 45_2, and they have a length sufficiently shorter than the wavelength at the resonance frequency of the plurality of series resonant circuits. The capacitor 45_3 consists of a chip capacitor.

Similarly, a second jump-coupling circuit 4_2 is constructed of a microstrip line 46_1, a capacitor 46_3, and another microstrip line 46_2, which are connected in series. The first microstrip line 46_1 has the same structure as the second microstrip line 46_2, and they have a length sufficiently shorter than the wavelength at the resonance frequency of the plurality of series resonant circuits. The capacitor 46_3 consists of a chip capacitor.

In the first jump-coupling circuit 4_1, the two microstrip lines 45_1 and 45_2 are formed so that the implementation of the capacitor 45_3 is facilitated for connecting a first open-ended stub 3_1 with a sixth open-ended stub 3_6 via the capacitor 45_3.

Similarly, in the second jump-coupling circuit 4_2, the two microstrip lines 46_1 and 46_2 are formed so that the implementation of the capacitor 46_3 is facilitated for connecting a second open-ended stub 3_2 with a fifth open-ended stub 3_5 via the capacitor 46_3. In some cases, these microstrip lines 45_1, 45_2, 46_1, and 46_2 can be omitted.

In the band rejection filter with poles according to this embodiment 3, each of the above-mentioned capacitors 45_3 and 46_3 consists of a chip capacitor. As an alternative, each of the above-mentioned capacitors 45_3 and 46_3 can consist of either a gap capacitor formed as a gap of a transmission line or an interdigital capacitor. Each of the transmission lines 2, 45_1, 45_2, 46_1 and 46_2 is formed of a microstrip line. As an alternative, each of the transmission lines 2, 45_1, 45_2, 46_1 and 46_2 can be formed of either a slot line or a coplanar line.

The band rejection filter with poles according to this embodiment 3 uses capacitors as first and second admittance inverters 40_1 and 40_2 each of which couples two of a plurality of series resonant circuits 30_1 to 30_{2n}, as shown in Fig. 2, which are not adjacent to each other, to each other. As previously explained with reference to Fig. 3, an admittance inverter having a negative parameter value of "$-J_i$" can be approximately replaced by a capacitor having a capacitance value of J_i/ω (ω is an operating angular frequency). Thus each jump-coupling circuit of the band rejection filter with poles can be implemented via a capacitor.

As previously explained, according to this embodiment 3, the first and sixth series resonant circuits 3_1 and 3_6 that are not adjacent to each other are coupled to each other via the first jump-coupling circuit 4_1 provided with a capacitor

45_3, and the second and fifth series resonant circuits 3_2 and 3_5 that are not adjacent to each other are coupled to each other via the second jump-coupling circuit 4_2 provided with a capacitor 46_3. Therefore, a band rejection filter with poles having two or more attenuation poles in its filter characteristics can be implemented. As a result, since the number of filters required for providing a desired attenuation can be reduced, the downsizing of the circuitry can be achieved.

Embodiment 4.

Figs. 7A and 7B are diagrams showing the structure of a band rejection filter with poles according to embodiment 4 of the present invention. Fig. 7A is a cross-sectional view of the band rejection filter with poles and Fig. 7B is a top plan view of the band rejection filter with poles. The band rejection filter with poles includes first and second metallic cavities 7_1 and 7_2 disposed on an upper wider wall face of a main waveguide 6, third and fourth metallic cavities 7_3 and 7_4 disposed on a lower wider wall face of the main waveguide 6, first through fourth dielectric resonators 8_1 to 8_4 contained in the first through fourth metallic cavities 7_1 to 7_4, respectively, and a jump-coupling waveguide 9 formed on a narrower wall face of the main waveguide 6.

The jump-coupling waveguide 9 has a width (i.e., a waveguide length) that is set so that the electric length thereof becomes about 90 degrees at the resonance frequency of the first through fourth dielectric resonators 8_1 to 8_4. Both ends of the main waveguide 6 are used as input/output terminals 10_1 and 10_2. A plurality of coupling holes 11_1 to 11_4 are formed between the main waveguide 6 and the first through

fourth metallic cavities 7_1 to 7_4, respectively. Two coupling holes 12_1 and 12_2 are also formed between the main waveguide 6 and the jump-coupling waveguide 9 and serve as a capacitor and another capacitor according to the present invention, respectively.

Next, the operation of the band rejection filter with poles will be explained. The equivalent circuit of the band rejection filter with poles according to embodiment 1, as shown in Fig. 2A, which includes a plurality of series resonant circuits, can be transformed into a band rejection filter with poles, as shown in Fig. 8, which includes a plurality of parallel resonant circuits. In this band rejection filter with poles, the plurality of parallel resonant circuits 80_1 to 80_{2n} are connected in series via a plurality of transmission lines 60_1 to 60_{2n-1} each having a length equal to of the one-quarter wavelength at the resonance frequency of the plurality of parallel resonant circuits.

A first admittance inverter 90_1 comprised of the jump-coupling waveguide 9 is connected between the first and 2n-*th* parallel resonant circuits 80_1 and 80_{2n}, and a second admittance inverter 90_2 comprised of the jump-coupling waveguide 9 is connected between the second and (2n-1)-*th* parallel resonant circuits 80_2 and 80_{2n-1}. Both the parameter J values of the first admittance inverter 90_1 and the parameter J values of the second admittance inverter 90_2 are both negative, and are represented by "$-J_1$" and "$-J_2$", respectively.

Input/output terminals 100_1 and 100_2 having source impedance Zo are disposed in the first and 2n-*th* parallel resonant circuits 80_1 and 80_{2n}, respectively.

On the other hand, in the band rejection filter with poles

shown in Fig. 7, the plurality of metallic cavities 7_1 to 7_4 and the plurality of dielectric resonators 8_1 to 8_4 operate as parallel resonant circuits, respectively. Since the jump-coupling waveguide 9 and the coupling holes 12_1 and 12_2 operate as a line having a length equal to the one-quarter wavelength at the resonance frequency of the parallel resonant circuits and capacitors, respectively, these components have the same functionality as the jump-coupling circuits of the band rejection filter with poles according to embodiment 1. Since the band rejection filter with poles having the structure as shown in Fig. 7 has the same characteristics as the band rejection filter with poles as shown in Fig. 8, i.e., the band rejection filter with poles as shown in Fig. 2A, the band rejection filter with poles having the structure as shown in Fig. 7 exhibits the same characteristics as the band rejection filter with poles in accordance with embodiment 1.

As previously explained, according to this embodiment 4, the two parallel resonant circuits that are not adjacent to each other are coupled to each other via the coupling holes 12_1 and 12_2 and the jump-coupling waveguide 9 that are provided on a narrower wall face of the main waveguide 6. Therefore, a band rejection filter with poles having two or more attenuation poles in its filter characteristics can be implemented. As a result, since the number of filters required for providing a desired attenuation can be reduced, the downsizing of the circuitry can be achieved.

Embodiment 5.

A band rejection filter with poles according to embodiment 5 of the present invention employs a waveguide

having a high impedance, a waveguide having a low impedance, and another waveguide having a high impedance that are connected in series, instead of the jump-coupling waveguide in accordance with embodiment 4.

Figs. 9A and 9B are views showing the structure of the band rejection filter with poles according to this embodiment 5, Fig. 9A is a cross-sectional view of the band rejection filter with poles, and Fig. 9B is a plan view of the band rejection filter with poles. The same components as those of embodiment 4 or like components are designated by the same reference numerals as shown in embodiment 1, and therefore the explanation of those components will be omitted hereafter.

As shown in Figs. 9A and 9B, the band rejection filter with poles according to this embodiment 5 is provided with two narrower and thicker jump-coupling waveguides 13 each having a high impedance which are connected to one narrower wall face of a main waveguide 6, and a wider and thinner jump-coupling waveguide 14 having a low impedance connected between the two narrower and thicker jump-coupling waveguides 13, instead of the jump-coupling waveguide 9 according to embodiment 4. The waveguide lengths of these waveguides are so set that their electric lengths become about 90 degrees at the resonance frequency of a plurality of dielectric resonators 8_1 to 8_4.

Next, the operation of the band rejection filter with poles according to embodiment 5 of the present invention will be explained. The band rejection filter with poles according to this embodiment 5 uses a plurality of parallel resonant circuits instead of the plurality of series resonant circuits according to embodiment 2, uses the main waveguide 6 instead of transmission lines, and further uses the jump-coupling

waveguides 13 and 14 instead of jump-coupling circuits. Therefore, the equivalent circuit of the band rejection filter with poles according to embodiment 5 is the same as the band rejection filter with poles as shown in Fig. 8, and exhibits the same filter characteristics as that of embodiment 4. In other words, the structure as shown in Fig. 9 can implement a band rejection filter with poles having the filtering features of the present invention.

As previously explained, according to this embodiment 5, the two parallel resonant circuits that are not adjacent to each other are coupled to each other via a waveguide in which a jump-coupling waveguide 13 having a high impedance and an electric length of about 90 degrees, a jump-coupling waveguide 14 having a low impedance, and another jump-coupling waveguide 13 having a high impedance are connected in series. Therefore, a band rejection filter with poles having two or more attenuation poles in its filter characteristics can be implemented. As a result, since the number of filters required for providing a desired attenuation can be reduced, the downsizing of the circuitry can be achieved.

Embodiment 6.

A band rejection filter with poles according to embodiment 6 of the present invention is the one in which a plurality of series resonant circuits 30_1 to 30_6 (i.e., a plurality of open-ended stubs 3_1 to 3_6) of embodiment 3 are replaced by a plurality of parallel resonant circuits 15_1 to 15_6 which are embedded in a transmission line 2.

Fig. 10 is a plan view showing the structure of the band rejection filter with poles according to this embodiment 6.

The same components as those of embodiment 3 or like components are designated by the same reference numerals as shown in embodiment 1, and therefore the explanation of those components will be omitted hereafter.

In the band rejection filter with poles according to this embodiment, the plurality of parallel resonant circuits 15_1 to 15_6 are embedded in the transmission line 2 and at intervals of a length equal to the one-quarter wavelength at the resonance frequency of the plurality of parallel resonant circuits. Each of the plurality of parallel resonant circuits 15_1 to 15_6 is constructed of a corresponding one of coils L_1 to L_6, which serves as an inductor, and a corresponding one of chip capacitors C_1 to C_6, the pair of coil and chip capacitor being connected in parallel.

Next, the operation of the band rejection filter with poles in accordance with this embodiment 6 of the present invention will be explained. The band rejection filter with poles according to embodiment 6 uses the plurality of parallel resonant circuits instead of the plurality of series resonant circuits of the band rejection filter with poles in accordance with embodiment 3. The equivalent circuit of the band rejection filter with poles in accordance with this embodiment 6 is the same as the equivalent circuit of the band rejection filter with poles shown in Fig. 9, and exhibits the same filter characteristics as the band rejection filter with poles according to embodiment 3. In other words, the structure as shown in Fig. 10 can implement a band rejection filter with poles having the filtering features of the present invention.

As previously explained, according to this embodiment 6, the first and sixth parallel resonant circuits that are not

adjacent to each other are coupled to each other via the first jump-coupling waveguide 4_1 provided with a capacitor 45_3 and the second and fifth parallel resonant circuits that are not adjacent to each other are coupled to each other via the second jump-coupling waveguide 4_2 provided with a capacitor 46_3. Therefore, a band rejection filter with poles having two or more attenuation poles in its filter characteristics can be implemented. As a result, since the number of filters required for providing a desired attenuation can be reduced, the downsizing of the circuitry can be achieved.

As previously mentioned, the band rejection filter with poles according to embodiment 6 is the one in which the plurality of series resonant circuits 30_1 to 30_6 of the band rejection filter with poles in accordance with embodiment 3 are replaced by the plurality of parallel resonant circuits 15_1 to 15_6. As an alternative, the band rejection filter with poles according to embodiment 6 can be the one in which the plurality of series resonant circuits 30_1 to 30_6 of the band rejection filter with poles in accordance with embodiment 1 or 2 are replaced by the plurality of parallel resonant circuits 15_1 to 15_6. The band rejection filter with poles of this variant operates in the same way as that according to above-mentioned embodiment 1 or 2, and this variant offers the same advantage as provided by above-mentioned embodiment 1 or 2.

Many widely different embodiments of the present invention may be constructed without departing from the spirit and scope of the present invention. It should be understood that the present invention is not limited to the specific embodiments described in the specification, except as defined in the appended claims.